ALBEDO MEASUREMENTS OVER THE NORTHEASTERN UNITED STATES

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ABSTRACT

On September 16, 1961, Eppley pyranometers mounted in a P2V–7 aircraft were used to measure the incoming and outgoing solar radiation fluxes at 7,500, 9,500 and 25,000 ft. along flight paths between Atlantic City, N.J., and Erie, Pa. Albedo values are determined from this information for the flight level. Simultaneous photographs and radiation values were obtained on the 25,000-ft. flight. The albedo for the high-level flight varied from 0.158 for no undercast to 0.538 for a complete altocumulus undercast. Two selected observations at 1722 GMT and 1737 GMT are further discussed. A solar radiation budget is prepared for the 1737 GMT measurement using the high-level flight data and ground data from Thornthwaite Laboratories near Elmer, N.J.

1. INTRODUCTION

On September 16, 1961 a flight was made in a Navy aircraft to test a high-level albedo-measuring technique for use in the Antarctic region.[1] The flight originated at Quonset Point Naval Air Station, R.I. In order to parallel the expected path of TIROS III over the eastern United States, the actual flight path was from Atlantic City, N.J., to Erie, Pa., at 7,500–9,500 ft. and return at 25,000 ft. (fig. 1). Satellite passage occurred at approximately the midpoint of the 25,000-ft. return flight, as is shown in figure 1 (bottom).

The flight path passed over the Atlantic coastal plain from the New Jersey coast to about Harrisburg, Pa., across the Appalachian Mountains from Harrisburg to the Allegheny River, and then over relatively level ground to Lake Erie. The plains and valleys were largely covered by towns and fields, while the hills were primarily wooded with some contour farming.

Observations were made of the incoming solar radiation, reflected solar radiation, clouds above and below the aircraft, and terrain features. The last two items were observed photographically only on the high-level return flight. The full photographic sequence is shown in figure 2 with identifying frame numbers. A comparison of frame numbers with albedo and surface features is shown in figure 3.

Synoptically, the eastern United States was dominated by a slow-moving High during the 6-hr. period covering the time of the flight. At this time hurricane Esther was located at 23°N., 61°W., well off the coast moving west-northwest. Its influence was not yet being felt on the weather in our area of interest. An extensive altocumulus cloud layer began to move eastward from the area of Lake Erie about 1200 GMT. It moved progressively eastward until it reached the vicinity of Harrisburg, Pa., by the time of the high-level flight around 1700 GMT (fig. 4). Between Harrisburg and the coast the clouds were primarily scattered fair weather cumulus.

2. INSTRUMENTATION

The recently developed Eppley spectral pyranometer was used for the measurements. As described by Marchgraber and Drummond [1], the principal features of this sensor are (a) a new thermopile detector, (b) optical compensation for reflection losses in the detector, and (c) a temperature compensation circuit. The instrument employs precision-ground hemispherical covers of clear or filter glass to enable either total radiation or spectral measurements over fixed wavelength intervals. Each pyranometer was attached to a specially prepared base by three adjustable, spring-loaded screws to allow leveling from within the aircraft.

Tests were made at Eppley Laboratories to determine the suitability of the temperature compensation circuits. Results of these tests, shown in figure 5, indicate that the instrument sensitivities vary by only a few percent over the range: 0° to −40°C. On this test flight, the thermopile output and temperature of the upper and lower pyranometers were measured. In the data reduction,

[1] With deep regret we note that the crew and aircraft crashed while accomplishing a scientific mission in Antarctica, November 9, 1961. To Lt.(jg.) R. P. Compton and Petty Officers W. R. Chastain, and J. L. Gray, who gave their lives supporting their country's scientific programs, and to Lt. E. J. Stetz, Lt.(jg.) E. L. Hand, and Petty Officers J. C. Shaffer and C. C. Allen, who were seriously injured, this work is humbly and sincerely dedicated.

pyranometer sensitivities were determined from actual pyranometer temperatures and the relationships in figure 5. This reduced considerably the possible error due to instrument temperature response.

Most of the test flight was made with clear WG–7 glass hemispheres on the pyranometers. However, measurements in the near-infrared were made with RG–8 hemispheres during a portion of the flight. Tests at Eppley Laboratories [2] indicate that the center of the lower cut-off of the RG–8 hemispheres is 0.694μ at 21°C., and that, in the main transmission bands, the transmittance of the RG–8 glass is 1.0 percent lower than that of the WG–7 glass. Therefore, the test flight measurements obtained with the RG–8 hemispheres have been increased by 1.0 percent.

The airborne measurements were obtained with a digital voltmeter and recorded by paper print-out. Each sensor was sampled every 10 sec. A P2V–7 reconnaissance aircraft was used as a platform for the measurements. A pyranometer housing was installed on the top of the aircraft in place of the navigator's astrodome and a similar housing was installed on the bottom of the aircraft, a few feet behind the retracted nose-wheel ski. Both locations were optimum positions for hemispherical radiation measurements as there were no significant obstructions by the aircraft. The housings were designed so that the sensors could be installed, removed, and leveled in flight. The recorder and operator were located directly below the upper pyranometer so the sensor could be leveled easily.

3. RADIATION OBSERVATIONS

TRACK NO. 1

This track was flown from Atlantic City, N.J., to Erie, Pa. (fig. 1) at altitudes ranging from 7,500 to 9,500 ft. The radiation measurements, shown in figure 6, are of interest in many respects.

Using the notation suggested by Fritz [3], consider the solar radiation fluxes through a given horizontal surface at height, h (thousands of ft.), and pressure, p (mb.):

$$h \underset{\downarrow}{Q_h} \overline{\qquad} \overset{B_h}{\uparrow} p$$

where Q_h is the total incident solar radiation and B_h is the total upward scattered solar radiation.

The observed values of $Q_{7.5}$ and $Q_{9.5}$ show a fairly smooth upward trend with time (fig. 6) similar to the corresponding extraterrestrial radiation (Q_t) values. This suggests that no significant change occurred in the level of the upper pyranometer during the flight. Minor exceptions are noted at 1430 and 1613 GMT on Track No. 1 and at 1707 and 1714 GMT on Track No. 2. However, these are of short duration and may be the result of changes in the level of the aircraft or high clouds above the aircraft. No high cloudiness was visible during this period, so that the first suggestion is the most likely explanation.

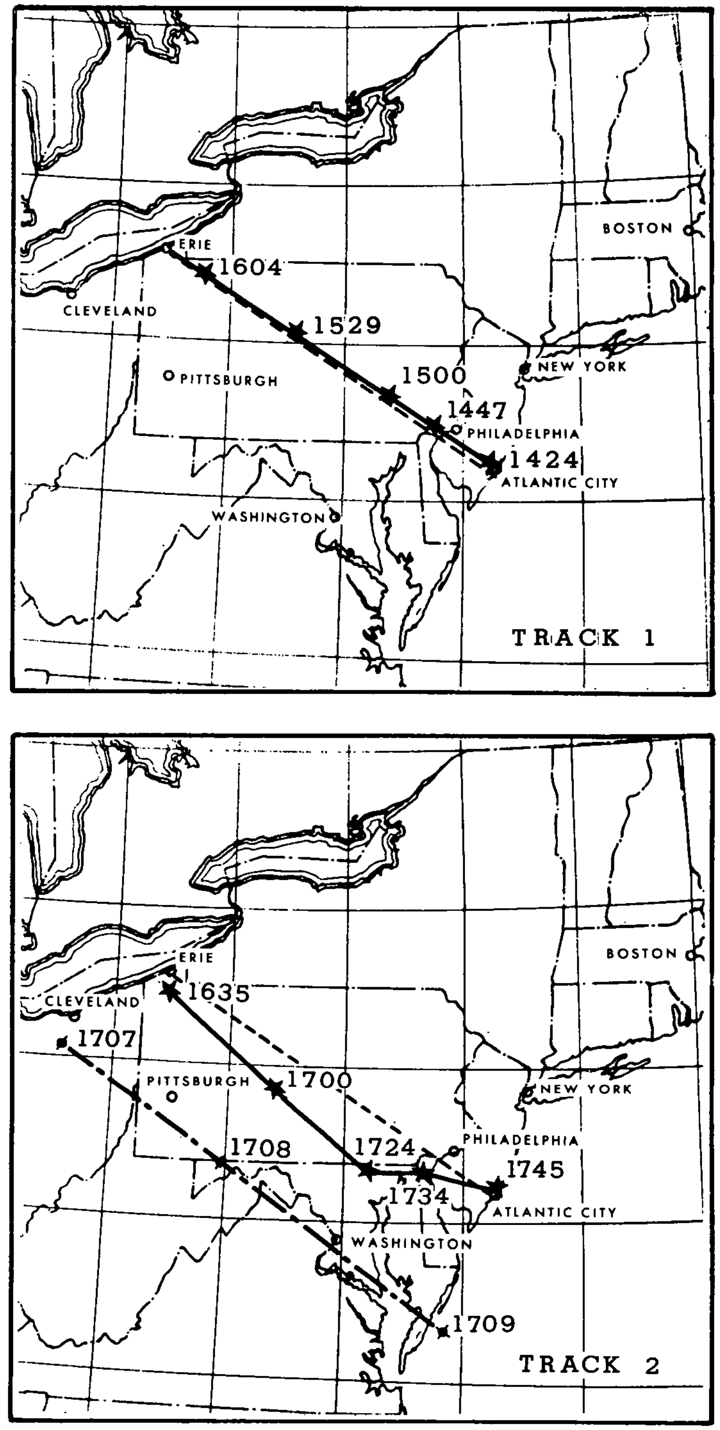

FIGURE 1.—The plane's flight path for Track No. 1 (upper) and Track No. 2 (lower). The times refer to the starred points and are in GMT. The dashed line is the proposed flight path, the solid line the actual flight path, and the dot-dash line the satellite path. Track No. 1 was at 7,500–9,500 ft. and Track No. 2 at 25,000 ft.

Measurements of the near-infrared solar fluxes were obtained with RG–8 hemispherical filters during the

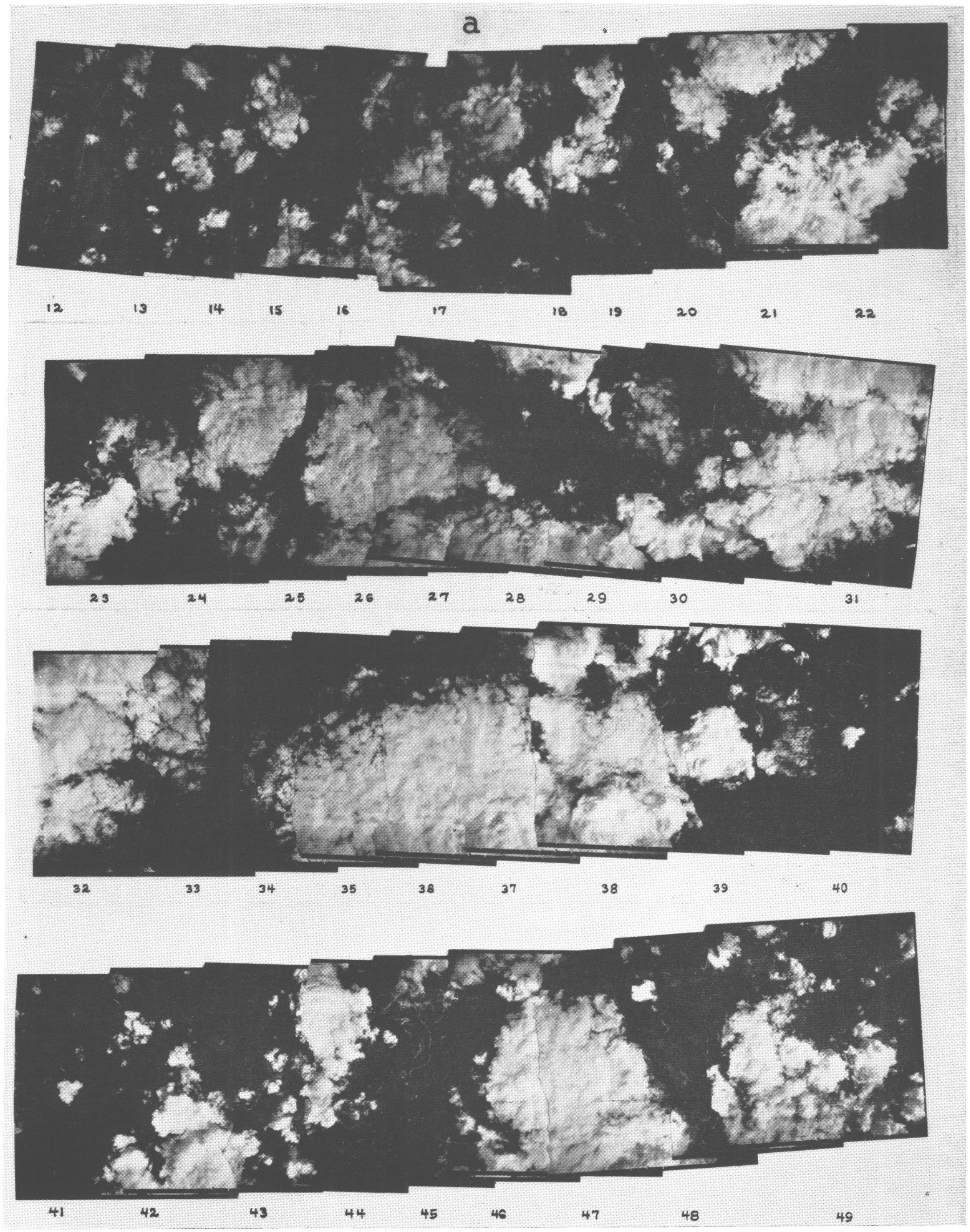

FIGURE 2.—Photographic sequence for Track No. 2 at 25,000 ft. The numbers below the frames of the mosaic refer to the abscissa of figure 3, which indicates the time and approximate location of the various frames. Continued on pages 226–228.

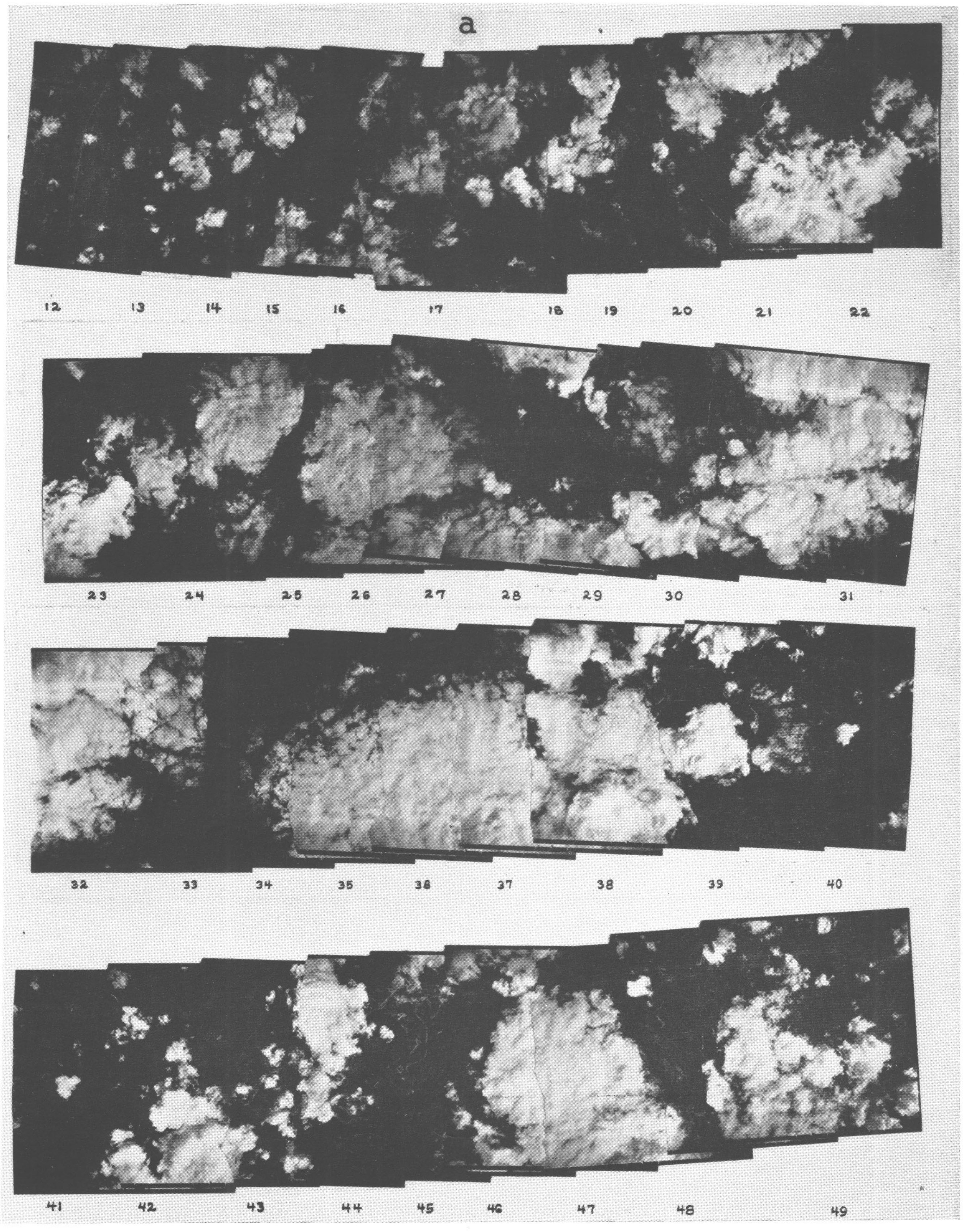

FIGURE 2.—Continued.

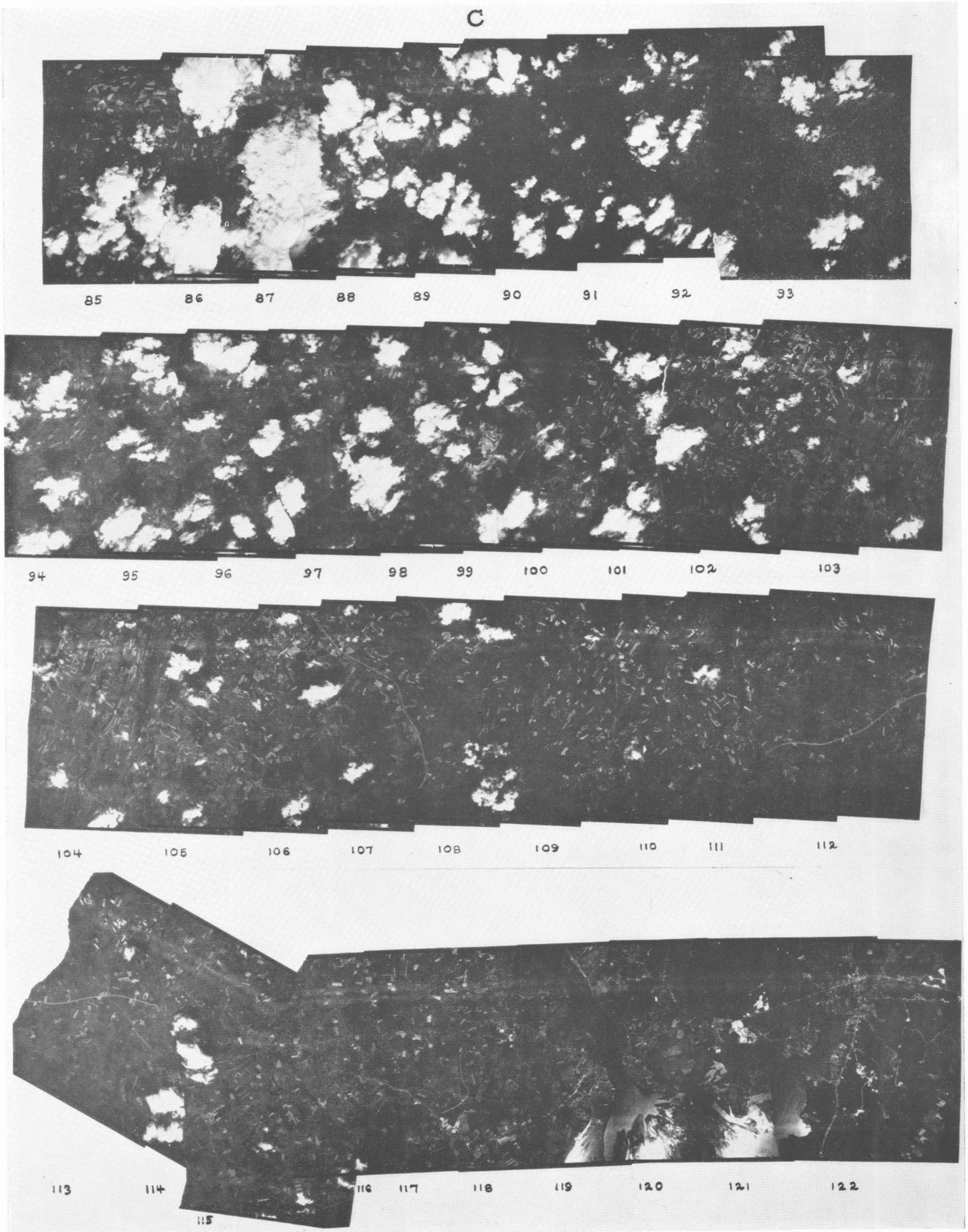

FIGURE 2.—Continued.

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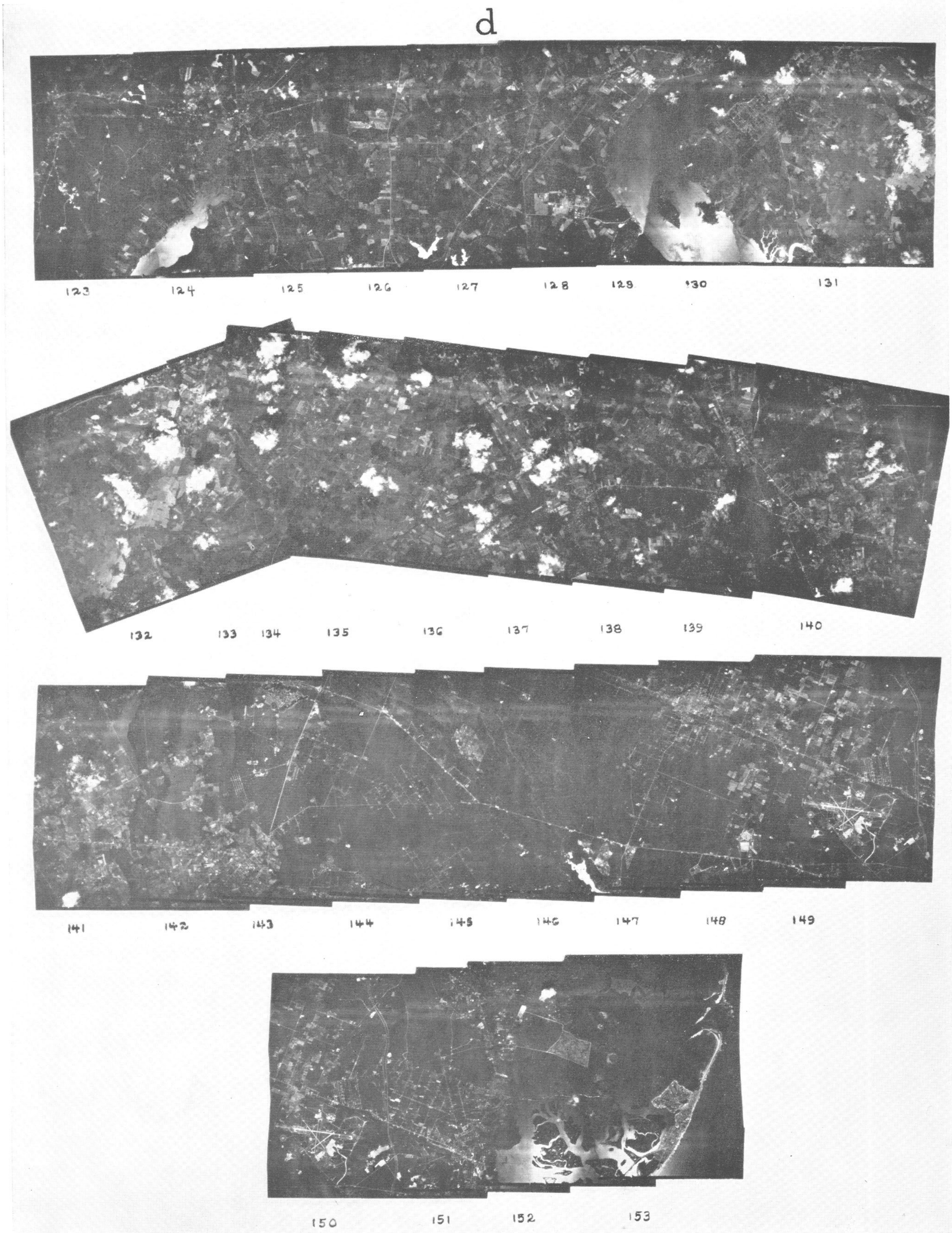


FIGURE 2.—Continued.

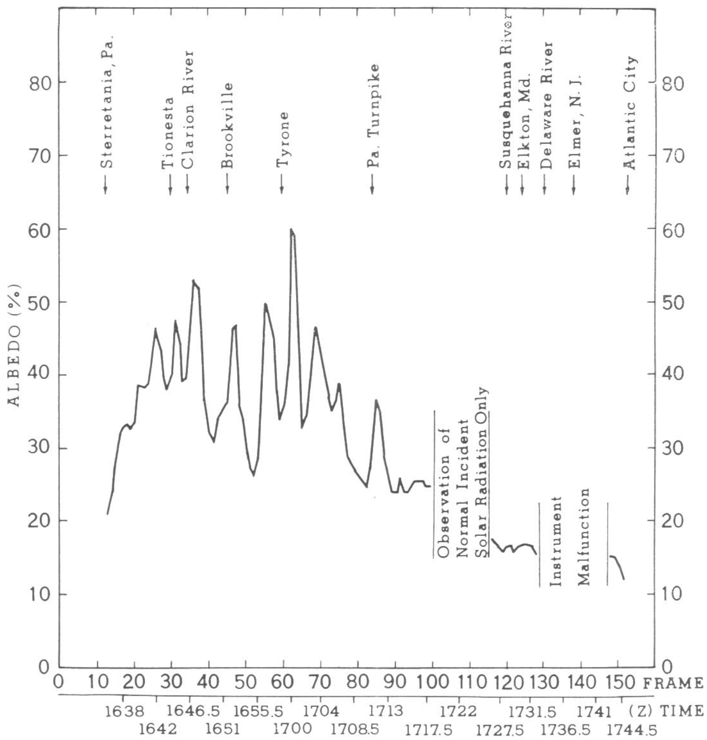


FIGURE 3.—A plot of the albedo values from Track No. 2 for each of the frames in figure 2. The time and terrain reference are given for orientation purposes.

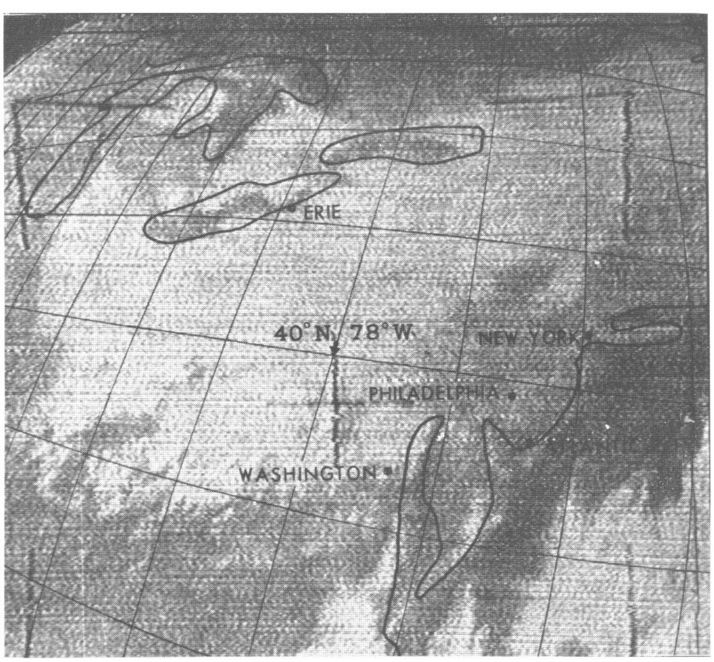


FIGURE 4.—A satellite photo from orbital pass 952 of TIROS III showing the cloud distribution over the eastern United States on September 16, 1961. Note the cloud deck from Lake Erie to central Pennsylvania.

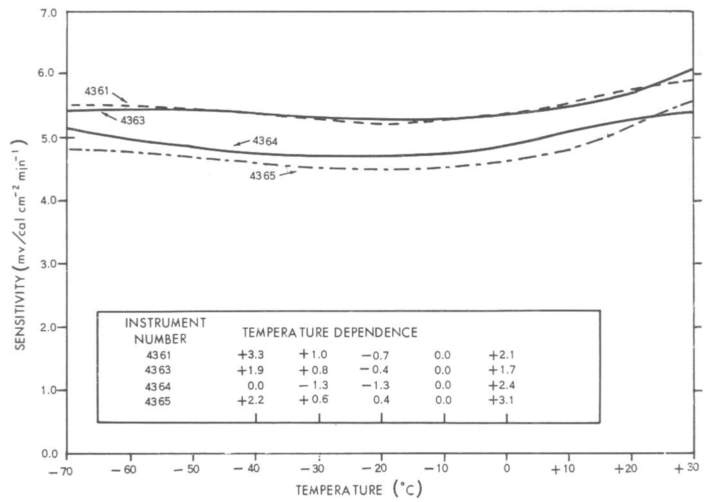


FIGURE 5.—A plot of the temperature dependency of the instrument sensitivity for the four Eppley pyranometers carried. Instruments 4363 and 4365 were installed, while the other two served as spares.

period 1547–1600 GMT. After correction for the filter factor and displacement of the lower cut-off with temperature (Hickey et al., [4]) measurements indicate that the near-infrared (0.69–4.0 μ) portion of $Q_{9.5}$ averaged 0.704 ly.*/min. During the same period $Q_{9.5}$ obtained by interpolation between the values before and after the period (fig. 6) was near 1.290 ly./min. This suggests that about 54.5 percent of $Q_{9.5}$ was at wavelengths $\geq 0.691\ \mu$. Outside the atmosphere approximately 52.5 percent of the solar radiation is at wavelengths $\geq 0.691\ \mu$ (List [5]). This indicates a greater depletion at the short-wave end of the solar spectrum above this level, as would be expected.

Albedo (A_h) values have been determined from the radiation data by

$$A_h = B_h/Q_h$$

As shown in figure 6, $A_{7.5}$ increased slightly across the farmlands of New Jersey from 0.14 near Atlantic City to 0.17 near the Delaware River. The apparent anomaly at 1440 GMT is an increase in $A_{7.5}$ to 0.20 over the industrial complex southwest of Philadelphia. This is followed by a decrease to 0.13 crossing the Delaware River.

$A_{7.5}$ values were very constant as the aircraft moved northwestward over the farm country of Pennsylvania. For example, from West Chester (1447 GMT) to Lebanon (1504 GMT), a distance of about 45 mi., $A_{7.5}$ averaged 0.179. The average departure of the individual measurements was less than 0.003. As the flight progressed over the tree-covered hills and farmed valleys of central Pennsylvania, $A_{7.5}$ values indicated changing terrain and varied from 0.17 to 0.19 until clouds were encountered

*1 langley (ly.)=1 gm. cal./cm.²

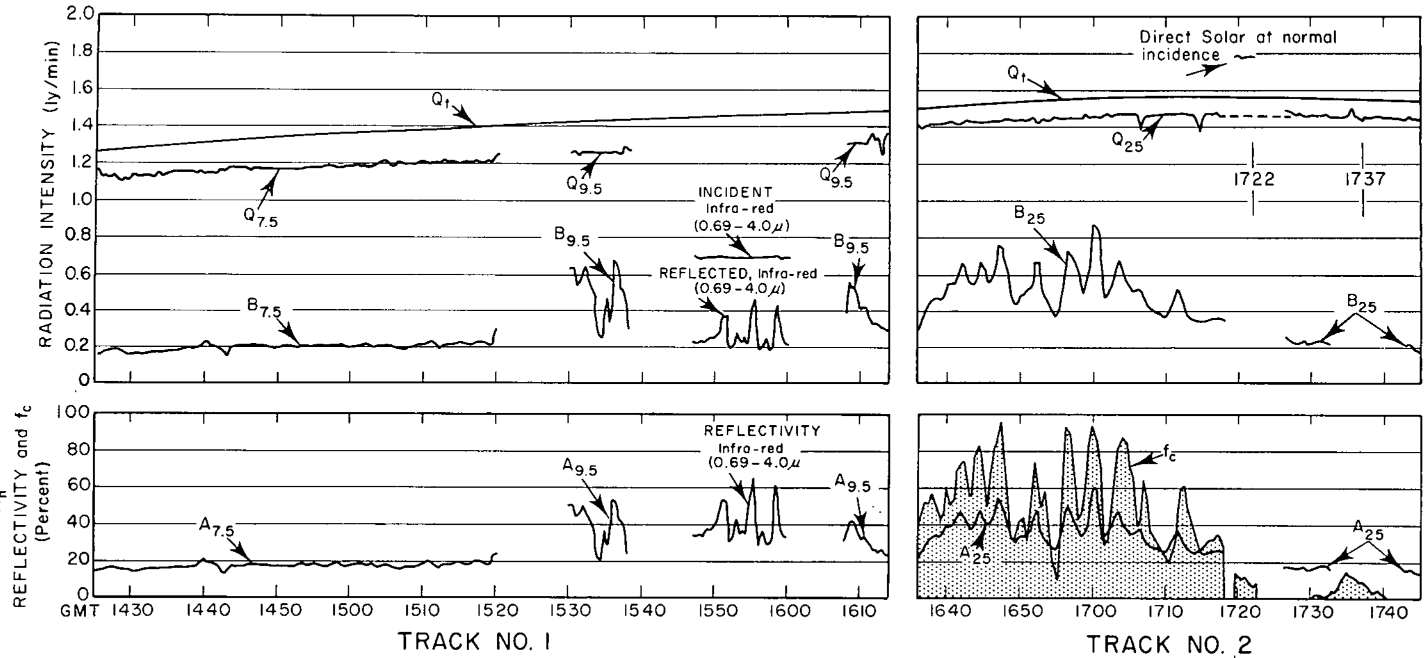


FIGURE 6.—A complete record of the radiation observations and albedo determinations for Track No. 1 and No. 2. $Q_{7.5}$, $Q_{9.5}$, and Q_{25} are the values recorded from the upfacing pyranometer. $B_{7.5}$, $B_{9.5}$, and B_{25} are from the downfacing pyranometer. $A_{7.5}$, $A_{9.5}$, and A_{25} are the computed albedo values. f_c is cloudiness determined from the aerial photographs. Q_t is the extraterrestrial radiation.

at 1520 GMT. For the remainder of Track No. 1, A values are of limited value because the cloud cover was only estimated visually.

TRACK NO. 2

This track was flown from Erie, Pa., to Atlantic City, N.J., at approximately 25,000 ft. Vertical photographs (fig. 2) of the underlying surface were taken along the entire flight track.

Simultaneous radiation measurements and photographs were obtained from 1636 to 1745 GMT. Following the flight each photograph was scanned with a 100-point grid to determine the relative amount of cloud and ground visible on the photograph. Cloud undercast (f_c) values of 0 to 98 percent were found. Figure 6 shows a plot of the undercast values with the albedo values. The general agreement between the shape of the curves is apparent. This is further discussed in the next section.

From 1720 to 1723 GMT the flux of the direct solar beam at normal incidence was measured with an Eppley pyrheliometer. A normal incidence pyrheliometer was used to obtain measurements of the direct solar beam through the navigator's astrodome, after the upper pyranometer was removed. The measurement was nearly constant at 1.785 ly./min. Assuming a solar constant of 2.00 ly./min. the flux of the direct solar beam outside the atmosphere would be 1.979 ly./min. at that time. The ratio of the two fluxes indicates that the transmission coefficient for the 0–400-mb. layer was 0.902.

The diffuse sky radiation at that time can be determined from (a) Q_{25} (1.470 ly./min.) obtained from interpolation between measurements of Q_{25} before and after that time, and (b) the flux of the direct solar beam on a horizontal surface at $h=25$(1.414 ly./min.) obtained from the direct measurement and corrected for a solar elevation of 52°22′. Computing the difference between (a) and (b) gives the flux of the diffuse sky radiation at $h=25$ as 0.056 ly./min. This implies that Q_{25} at 400 mb. was composed of 3.8 percent diffuse radiation and 96.2 percent direct radiation (table 4).

At 1737 GMT the flight passed over Elmer, N.J. This provided a comparison with surface measurements made at the Thornthwaite Laboratories in Centerton, N.J., about 6 mi. south of the flight track. This will be discussed in section 5.

4. ALBEDO OF CLOUDS

From the data of Track No. 2 simultaneous values of the fraction of altocumulus undercast (f_c) and cloud albedo (A_c) were obtained for the cloud layer covering much of central Pennsylvania (fig. 4). The f_c values were grouped into classes and mean values of A_c and f_c were determined for each class. Table 1 presents the results, which are plotted in figure 7.

With no cloud cover and $f_c=0$, A_c averaged 0.158; whereas, for all observations with some clouds present, f_c averaged 50.2 percent and A_c averaged 0.348. Figure 7 shows the regression line for these data:

$$A_c=0.380\, f_c+0.158$$

Based on this relationship, A_c for a complete altocumulus undercast is 0.538.

TABLE 1.—*Average fraction of undercast (f_c) and cloud albedo values (A_c) summarized by f_c classes. Data obtained on Track No. 2, 25,000 ft., September 16, 1961, from Erie, Pa., to Atlantic City, N.J. The average was obtained using all observations except the 0 percent undercast values*

f_c class (percent)	No. Obs.	f_c (percent)	A_c
0	14	0.0	0.158
1–10	5	2.4	0.179
11–20	2	17.0	0.274
21–30	11	26.6	0.273
31–40	14	33.9	0.280
41–50	16	45.9	0.339
51–60	11	55.1	0.366
61–70	8	65.5	0.372
71–80	10	73.9	0.434
81–90	9	85.4	0.470
91–100	3	95.3	0.541
Average	------	50.2	0.348

TABLE 2.—*Comparison of radiation intensities on present IPS scale and formerly used Smithsonian scale. Intensities apply to 39°47′N., 76°59′W. at 1722 GMT, September 16, 1961*

Level	Intensity of direct solar beam at normal intensity (ly./min.)	
	Current values	Equivalent Smithsonian values
0 mb	*1.979	**1.920
400 mb	†1.785	‡1.821
Transmissivity in the 0–400-mb. layer	0.902	0.949

*Based on solar constant of 2.00 ly./min.
**Based on solar constant of 1.94 ly./min.
†Measured value expressed in IPS scale of 1956.
‡Measured value expressed in Smithsonian scale.

5. ATMOSPHERIC SCATTERING AND ABSORPTION

0–400-MB. LAYER

As previously stated the flux of the direct solar beam measured at 1722 GMT near Hanover, Pa., was 1.785 ly./min. This is a high value and therefore deserves further comment. The pertinent associated data are: (1) flight level was 24,330 ft. (400 mb.); (2) solar elevation was 52°22′; (3) position was 39°47′N., 76°50′W.; (4) total precipitable water above the 400-mb. level was 0.04 cm.; and (5) the optical air mass was 0.496.

To make an estimate of the amount of scattering and absorption in the 0–400-mb. layer, Kimball's [6] nomogram was used; however, the nomogram is based on radiation measurements in the Smithsonian scale and a solar constant of 1.94 ly./min. Therefore, our values, labeled "current" values in table 2, have been recomputed in the Smithsonian scale and for a solar constant of 1.94 ly./min. These values are shown in the last column of table 2.

The transmissivity computed for the 0–400-mb. layer for both sets of values is shown in table 2. The value based on the "equivalent Smithsonian values," 0.949, is comparable to Kimball's value for these conditions, which is 0.936. The difference between these values is 1.3 percent, which is considered within the accuracy of the determination.

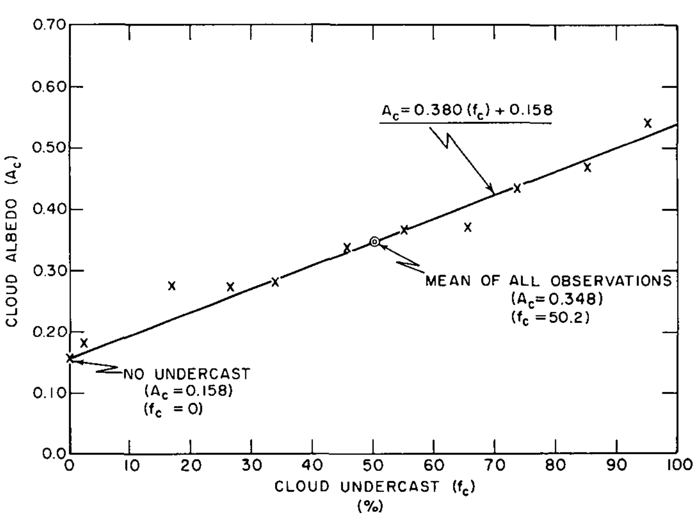


FIGURE 7.—Cloud albedo (A_c) versus cloud undercast (f_c) for Track No. 2. The data are listed in table 1.

With use of Kimball's nomogram for scattering and absorption, it is seen from table 3 that 77 percent of the total depletion in the 0–400-mb. layer is due to scattering and 23 percent to absorption.

The radiation fluxes at 1722 GMT near Hanover, Pa., are given in table 4. The *total* depletion of the direct solar beam incident on a horizontal surface is 0.153 ly./min. Assuming that the 77 percent value for depletion due to scattering determined above is applicable to the table 4 data, we find the depletion from scattering effects is 0.118 ly./min. If it is further assumed that the scattering is almost entirely caused by small particles and that Rayleigh's law is therefore applicable, then the scattered radiation flux at the lower boundary is one-half the total depletion for scattering or 0.059 ly./min. This is in good agreement with the value of 0.056 ly./min. derived from the measurements in section 3. Therefore, we may assume that in the 0–400-mb. layer the downward and upward scattered radiation streams are each 3.8 percent of the radiation incident on a horizontal surface at the top of the atmosphere (Q_t).

400–1017-MB. LAYER

At 1737 GMT the aircraft was near Elmer, N.J., approximately 6 mi. north of the location of the Thornthwaite Laboratories. Thus, it was possible to make a comparison between the measurements at flight level (Q_h) and at the ground (Q_g).

TABLE 3.—*Transmission coefficients for the layer 0–400 mb. Values based on Kimball's [6] nomogram, total precipitable water=0.04 cm. and optical air mass=0.496*

	Transmission coefficients	Fraction of total depletion (percent)
a'_m (scattering only)	0.950	77
a (absorption only)	0.985	23
a''_m (scattering and absorption)	0.936	100

TABLE 4.—*Radiation fluxes near Hanover, Pa., 1722* GMT, *September 16, 1961. Values in parentheses are computed values*

Level	Direct Solar Beam		Diffuse sky radiation (ly./min.)	Total solar radiation (ly./min.)
	At normal incidence (ly./min.)	Incident on a horizontal sfc. (ly./min.)		
0 mb	*(1.979)	*(1.567)	0	(1.567)
400 mb	1.785	1.414	(0.056)	1.470

*Based on a solar constant of 2.00 ly./min.

The radiation fluxes are listed in table 5 with the computed values in parentheses. At 25,000 ft. the sky was clear above the aircraft and Q_{25} was 1.460 ly./min. However, there was some cloudiness below the aircraft and a direct clear sky measurement of Q_g could not be obtained. Assuming symmetry of the Q_g curve with respect to solar noon, the intensity of Q_g measured at the Thornthwaite Laboratories with clear skies before solar noon was used to obtain a value at 1737 GMT (1242 TST) of 1.025 ly./min.

To determine a representative albedo with clear skies in the vicinity of Elmer, N.J., measurements of $Q_{7.5}$ and $B_{7.5}$ taken several hours earlier on Track No. 1 were used. $A_{7.5}$ was found to be 0.150.

Although albedo values based on measurements are not available for other levels, it is possible to compute A values for other levels by assuming a form of the height dependence of the albedo. Assume an expression of the form:

$$A_{h'}=A_h-C(\Delta p),$$

where h' is less than h, C is a constant and Δp is $p_h-p_{h'}$. From measurements over Missouri, Fritz [3] found $C=-1.38\times10^{-4}$. Kuhn and Suomi [7] obtained measurements in the Midwest and found that A_h increased 1 percent for each 4,000 ft. In the lower atmosphere this gives $C=-0.79\times10^{-4}$. We have assumed the average of these two values, $C=-1.08\times10^{-4}$, for purposes of this discussion.

Thus with $A_{7.5}=0.150$ and $\Delta p=-242$ mb., the ground albedo (A_g) in the vicinity of Elmer, N.J., was determined as 0.124. Similarly A_{25} was found to be 0.190. The latter computation was necessary because the signal from the lower pyranometer was lost around 1737 GMT (fig. 6). In any case the presence of clouds below the aircraft precluded the measurement of a clear sky value of A_{25}. However, an examination of A_{25} in figure 6 before and after the instrument failure indicates that A_{25} based on direct measurement is lower than the computed value. Since there was no marked change in the underlying terrain, this is possibly a result of assuming an unrepresentative value of C for these conditions.

Using the values of Q_h and A_h for the ground and 25,000-ft. levels, values were computed for B_h, the upward-scattered solar radiation flux.

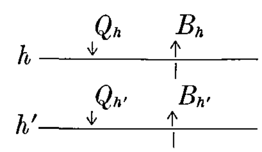
TABLE 5.—*Radiation fluxes and albedoes near Elmer, N.J., at 1737* GMT, *September 16, 1961. Values in parentheses are computed values*

h	p_h (mb.)	Q_h (ly./min.)	B_h (ly./min.)	A_h
t	0	(1.557)	(0.336)	(0.216)
25	402	1.460	(0.277)	(0.190)
7.5	775			0.150
g	1017	1.025	(0.127)	(0.124)

TABLE 6.—*Atmospheric absorption* ($G_{h-h'}$) *and net upward scattering* ($S_{h-h'}$) *at 1737* GMT

Layer (mb.)	$G_{h-h'}$		$S_{h-h'}$ (ly./min.)
	(ly./min.)	(°C./min.)	
0–402	0.038	0.00039	0.059
402–1017	0.285	0.00193	0.150

As shown in table 5, $B_g=0.127$ ly./min. and $B_{25}=0.277$ ly./min. In addition, a determination of B_t is needed. This is computed as follows. Continuing the notation of Fritz [3], consider the layer of atmosphere between heights h and h'.



The net upward scattering ($S_{h-h'}$) in the layer between h and h' is given by:

$$S_{h-h'}=B_h-B_{h'}.$$

For the measurements near Elmer, N.J., S_{25-g} is 0.150 ly./min. (table 6). It is not possible to compute S_{t-25} in a similar manner without a measurement of B_t from the top of the atmosphere. Although this was attempted, the meteorological satellite data were not of sufficient quality to be useful because of the deterioration of the TIROS III radiometer resolution with time. However, a good estimate of S_{t-25} can be made from the measurements at 1722 GMT. It was previously determined from these measurements that S_{t-25} was 3.8 percent of Q_t. Assuming this relationship is applicable at 1737 GMT (15 min. later), then S_{t-25} is 0.059 ly./min. and the total upward scattering at the top of the atmosphere, B_t, is 0.336 ly./min.

The final step in completing table 5 is to compute A_t. This was computed from values of Q_t and B_t and was found to be 0.216. Thus, it appears that A increased from 0.124 at ground level to 0.216 at the top of the clear atmosphere over central New Jersey.

ATMOSPHERIC ABSORPTION

The rate of absorption of solar radiation ($G_{h-h'}$) in the layer between h and h' is determined as the difference between the total inward and total outward radiation fluxes at h and h':

$$G_{h-h'}=(Q_h+B_{h'})-(Q_{h'}+B_h).$$

Computation of the radiative absorption rate at 1737 GMT for the 0–400-mb. layer indicates G_{t-25} is 0.038 ly./min. Similarly for the 400–1017-mb. layer G_{25-g} is 0.285 ly./min. These values are given in table 6 together with the corresponding heating rates that would result if the temperature change were uniform throughout the layer. The heating rate has been calculated from:

$$\frac{\Delta T}{\Delta t}=\frac{1}{Mc_p}G_{h-h'}$$

where M is the mass in grams of a 1 cm.^{2} column between h and h' and is approximately equal to $-\Delta p$, c_p is the specific heat of air at constant pressure, and t is time.

The measurement time is 1737 GMT or 1242 TST and therefore the $\Delta T/\Delta t$ values are fairly representative of the hour after solar noon. A computation of the hourly change gives $\Delta T/\Delta t$ as 0.023°C./hr. for the 0–400-mb. layer and 0.116°C./hr. for the 400–1017-mb. layer. From measurements over Missouri on March 22, 1948, Fritz [3] found that, at 0920 TST, $\Delta T/\Delta t$ was 0.05°C./hr. for the lower 10,000 ft. of atmosphere. Assuming $\Delta T/\Delta t$ is proportional to Q_t, the total heating from sunrise to sunset can be determined using the daily value of Q_t. A computation for Elmer, N. J., where the daily Q_t on September 16 is near 743 ly., gives $\Delta T/\Delta t$ as 0.19°C./day for the 0–400-mb. layer and 0.92°C./day for the 400–1017-mb. layer. A similar computation based on Fritz's data for Missouri, where the total daily Q_t on March 22 is 770 ly., gives $\Delta T/\Delta t$=0.50°C./day in the lower 10,000 ft.

6. ATMOSPHERIC RADIATION BUDGET

The radiation values for 1737 GMT, as given in table 5, are assumed to be representative of clear sky conditions for the agricultural area around Elmer, N.J., on September 16, 1961. This region consisted of 25 percent woodland and 75 percent fields and pastures, the main crops being lima beans, corn, pumpkin, alfalfa, and potatoes at this time of year [8]. A radiation budget given in relative units, where Q_t is 100 units, is listed in table 7 and illustrated in figure 8. Nearly 66 units are incident at the surface, of which 58 are absorbed by the vegetation and the ground. About 22 units are reflected to space; 8 of the 22 units are reflected from the ground; and the remaining 14 are scattered upward by the atmosphere. The absorption totals 20 units, 2 of which are absorbed above the 400-mb. level and 18 below. It must be re-emphasized here that this budget applies only to clear skies over Elmer, N.J., at this time.

TABLE 7.—*Radiation budget, central New Jersey, September 16, 1961, clear skies. (Values are in percent of* Q_t*)*

Levels				Layers			
h	Q_h	B_h	G_h	$h-h'$	$Q_{h-h'}$	$B_{h-h'}$	$G_{h-h'}$
t	100.0	21.6	----------	$t-25$	6.2	3.8	2.4
25	93.8	17.8	----------	$25-g$	27.9	9.6	18.3
g	65.8	8.2	57.7	$t-g$	34.2	13.4	20.7

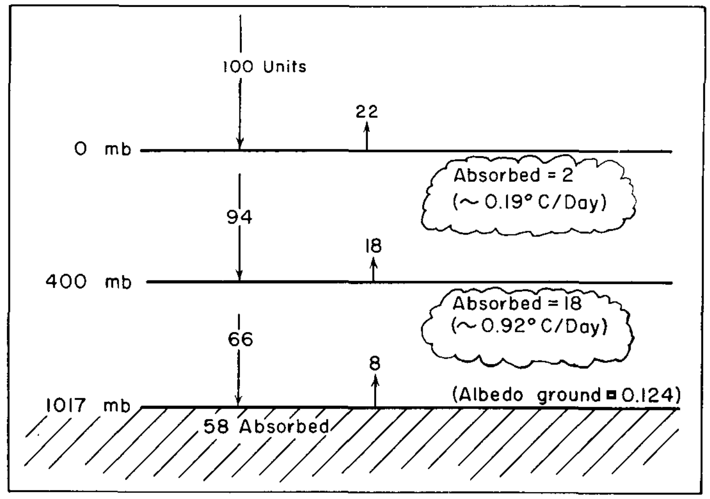


FIGURE 8.—The radiation budget for the vicinity of Elmer, N.J., on September 16, 1961, at 1737 GMT. All the values in the diagram are based on the incoming radiation at the top of the atmosphere equal to 100 units.

7. CONCLUSIONS

The flight was made on September 16, 1961, primarily to test an airborne technique for measuring upward and downward solar radiation fluxes. In this respect the flight was highly successful and the technique has since been used in the Antarctic to determine the albedo of snow and ice surfaces.

The data acquired on the flight were used to examine the albedo of an altocumulus cloud distribution and to determine the radiation budget for a given point with clear skies. On the high-level flight, the albedo varied from 0.158 with no undercast to an estimated 0.538 for a complete altocumulus undercast.

An estimated solar radiation budget was computed for Elmer, N. J. with clear sky conditions (fig. 8). Of the incoming solar radiation at the top of the atmosphere, 58 percent is absorbed by the underlying surface, 8 percent reflected by the ground, 14 percent scattered upward by the atmosphere, and 20 percent absorbed by the atmosphere. The last value gives a temperature rise of 0.19° C./day for the 0–400-mb. layer of the atmosphere and 0.92° C./day for the 400–1017-mb. layer.

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